PROMISING LINES OF AGRICULTURAL ENGINEERING RESEARCH

By
R. W. Trullinger,
Assistant in Experiment Station Administration,
(Agricultural Engineer)
Office of Experiment Stations, U. S.
Department of Agriculture.

The efforts of those engaged in agricultural pursuits to get the largest possible returns for their labor and the capital invested appear to show that the attainment of economy and efficiency in agricultural production can be materially advanced by the intelligent application of the principles of the various branches of engineering to specific agricultural practices.

Undertakings of this character, while productive of much of an immediately practical nature, have so far served to show that the engineering requirements of agriculture are, to a considerable extent, unlike those in any other industrial field, and the necessity for the development of new data and, in many cases, of entirely new engineering principles has been strongly evident. The need is apparent, therefore, for thoroughgoing studies of several of the important and expensive agricultural operations, especially those involving the use of power and labor, to establish their full requirements and thereby provide bases for engineering developments to satisfactorily meet such requirements permanently, economically and in a fundamentally sound manner.

This would suggest that the origin of a program of research in agricultural engineering at an agricultural experiment station should lie primarily in the program of agricultural research already existing at the station. Assuming that the station program is organized as a whole to meet the needs of the agriculture of the State, it seems logical to determine in what of its features agricultural engineering cooperation is needed and can contribute most effectively to its ultimate

ultimate specific aims in order to arrive at the most promising lines of agricultural engineering research which a station can undertake. Attention is drawn in the following to a few outstanding cases of this nature which are typical of a large number observed in a first-hand study of the programs of research at a large proportion of the experiment stations during annual official visits.

CROP PRODUCTION

Crop production requires a tremendous annual expenditure of labor and power and, therefore, offers perhaps the biggest field for profitable agricultural engineering research. An analysis of all of the operations involved in the production of a crop, from the time the seed bed is first prepared and the crop planted to the time the crop is harvested and housed, will show where the power and labor is expended in the largest amounts, and should also indicate the points at which engineering studies can be inaugurated most profitably.

It is known for example, that varying with locality, from 45 to 65 per cent of the total cost of producing a crop of corn is represented by the power and labor expended in the different operations involved. In other words, the biggest expense of corn production lies in those features susceptible of modification by engineering manipulation and this seems to hold true for most of the major cultivated crops. Undoubtedly, this situation has been relieved to some extent by better management of the necessary operations and the mechanical equipment used. The fact has been brought out, however, that the methods of procedure used and the available equipment are sometimes not adequate to fully meet the actual requirements of certain necessary operations. It is also being found in some cases that the underlying physical principles of the operation involved are not fully known, and the logical conclusion is that these principles must be elucidated to permit the logical and sound development of procedure and mechanical equipment to fully meet the requirements of a necessary operation most economically.

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Tillage.--In corn and other row crop production, tillage for example, is one of the outstanding necessary practices which has been found in all its phases to exceed practically every other necessary operation as a consumer of labor and power. It involves the preparation of the seed bed and the cultivation of the growing crop and offers two lines of research, which appear promising especially in localities where the soils are difficult to till properly or have low tractive properties. These lines call naturally for the coordination of the forces of soil technology and agricultural engineering. They are (1) the fundamental improvement of the tillage machinery so that it will satisfactorily meet the seed bed and cultivation requirements of the crop concerned with a minimum consumption of labor and power, and (2) the fundamental improvement of the traction machinery to meet the severe conditions imposed in the operation of the tillage machinery more efficiently and economically.

These lines of work have already been recognized at some of the experiment stations. The studies at the Alabama Station on the relation of the dynamic properties of the soil to the elements of tillage implement design and on the fundamental factors in soils influencing the traction of wheel tractors are outstanding examples of work calculated to introduce economy and efficiency into soil tillage practices from both the tillage and the traction ends where the soils concerned present problems from both standpoints. They also indicate a recognition of the importance of elucidating the scientific soils principles governing tillage and traction to provide a sound basis for the development of tillage and traction methods and mechanical equipment. Equally as striking and important in this

and of the dynamics of field machines. The Iowa and Nebraska Stations also are studying the factors involved in the draft of tillage machines with the idea of introducing greater economy and efficiency into their operation by readjustment and improvement. These studies have been inaugurated through the realization that the present methods of use of available tillage and traction machinery and, in many cases, the machines themselves are not yet fully adequate to meet most economically and efficiently the tillage requirements of some cultivated crops in certain soils, and that efforts for their redevelopment must be fundamentally sound.

Use of Fertilizers.--The use of fertilizers is one of the practices which is apparently necessary for the satisfactory production of some of the major crops. The fact that American agriculture consumes between 7 and 8 million tons of fertilizers annually suggests that this practice represents one of the big items of expense in crop production.

It seems important therefore that the most efficient use be made of fertilizers, and some of the experiment stations have pointed to proper placement of these materials in the soil as one of the major factors in this connection. The Iowa and New Jersey Stations have shown already that the manner and position of placement of fertilizer materials may very materially influence its efficient use by different crops. The problem has assumed so much importance that a joint committee has been formulated representing the American Society of Agronomy, the National Fertilizer Association, The National Association of Farm Equipment Manufacturers, and the American Society of Agricultural Engineers to consider the matter.

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It seems likely that a logical attack on this problem will necessitate a combining of the forces of agronomy and agricultural engineering to establish the requirements of proper placement of fertilizer materials for different crops, and to permit the rational development of methods and mechanical equipment which will meet these requirements. Some features of this work have already considered the physical characteristics of certain fertilizer materials under different conditions of temperature and humidity and of the mechanical means necessary for properly handling them. As a line of agricultural engineering inquiry this work, therefore, appears to be promising.

Harvesting.--It is being recognized that the development of satisfactory and economical methods and equipment for the harvesting of crops calls for the coordination of the forces of agronomy and agricultural engineering. For example, work is under way in some localities on the breeding of peas and beans which will permit harvesting with available machinery. The breeding process is long, expensive, and tedious with no assurance of full success in the long run. Here it seems is an opportunity for profitable engineering effort to study the conditions and requirements for harvesting these crops, as they have been developed so far, with the aim of modifying available machines or of developing the principles of new ones which will perform this important operation satisfactorily.

A somewhat similar problem is presented in the harvesting and threshing of grain. Several stations have made surveys of combining practice recently, the results of which, in addition to serving their purpose from the farm management standpoint, have pointed to the importance of further analytical studies of available

developed by the latter Station for the bulk handling of grain, for example, suggests that efforts to secure greater economy and efficiency in specific details of the grain combining process are promising agricultural engineering undertakings.

In a similar manner the Pennsylvania Station has brought to light the deficiencies of present methods and available machinery for potato harvesting from both the mechanical and economical standpoints and is setting out to correct them. The large amount of labor required for picking up dug potatoes suggests the specific features of potato digging and elevation as promising lines of engineering study. The picking and husking of the corn crop is another harvesting operation which, next to tillage, is probably the greatest consumer of labor and power of the operations involved in corn production. The mechanical performance of this operation is a great achievement in the substitution of mechanical devices for hand labor, but the Pennsylvania Experiment Station has shown that much is yet to be done toward bringing this process to a maximum of efficiency and economy.

Crop Processing.--Profitable opportunities for engineering research also exist in stationary farm operations involved in crop processing as is indicated by the progress made at the Wisconsin Experiment Station on the development of silage cutting and elevating methods and equipment and at the Wisconsin, Illinois, Kansas, and Indiana Stations on corn, hay, and grain drying methods and equipment. These undertakings recognize the requirements of the finished products as determined by the agronomists and are endeavoring to meet them satisfactorily and economically with the aim of increasing the value of the resulting crop.

ANIMAL PRODUCTION

As the knowledge of the relation of the productiveness of hogs, beef cattle, dairy stock, and poultry to their surroundings increases it is becoming evident that housing conditions which control temperature, air movement and supply, and humidity are important factors in the profitableness of the animal, dairy, and poultry industries.

Dairy Stock.--Dairy stock of different breeds are now known to present individual requirements for ventilation, temperature, and humidity maintenance for maximum production, and preliminary work at one station, for example, has also indicated a relation between the quality of milk and the temperatures inside and outside the barn. Some valuable work has already been done by engineers in the development of ventilation methods and equipment for dairy barns and in the development of technique for controlling and studying air movement and temperature and humidity conditions in barns. It seems likely, however, that a closer coordination of the forces of dairy husbandry and agricultural engineering, to more clearly develop the requirements to be met in dairy barns for economical maximum quality production by dairy stock, will materially strengthen this important work. An adequate control technique seems of considerable importance in this work, and the development of this together with studies of materials and equipment to provide the conditions of air movement and temperature required appear to constitute a promising line of agricultural engineering research.

Poultry Production.--The housing of poultry to provide conditions for maximum economic production is presenting quite a problem. For instance, controlled studies at the Iowa Experiment Station of the air and temperature requirements of poultry have cast some doubt on the validity of previously accepted theories regarding the conditions which should prevail in poultry houses. They have shown, for example, that air purity in a poultry house is not so important a factor in

the health and productiveness of poultry as are temperature and rates of air movement. Progress has already been made in this work in specifying the conditions which should prevail in poultry houses and in expressing them quantitatively.

A coordinated attack on this problem by the forces of poultry husbandry, poultry pathology, and agricultural engineering would appear to be a logical undertaking with particular reference to the establishment of the housing requirements for definite sets of conditions. The importance of an adequate control technique has already been demonstrated at the Iowa Station, and the provision of this appears to be a logical function of the agricultural engineers. The fact that available engineering knowledge is not always fully adequate to permit the expression of optimum poultry house conditions in terms of usable engineering specifications would appear to argue the importance of further studies of the principles of air movement and of temperature and humidity control corresponding to these conditions, which will provide a sound and economical basis for the selection of materials and methods of construction of poultry houses and for the design of ventilating and heating equipment where needed.

CROP STORAGE

Fruit and vegetable storage has always been a problem on the farm. That present knowledge is not fully adequate to meet the storage problem is indicated by the fact that storage practice now usually allows for a certain percentage of loss in the stored products. In recent years studies of temperature and humidity conditions in existing storages have indicated quite a wide variation in the quality of the stored products with a sometimes relatively slight variation in the storage conditions. The Massachusetts and Indiana Stations have shown a relation between temperature and humidity in storages and the keeping qualities of apples

for example. Variations in the storage requirements to produce proper culinary quality has also been established in different kinds of fruit and vegetables. The Maryland Station has shown, for example, that carrots and white potatoes require practically opposite conditions so far as temperature is concerned, owing to the desirability of a high sugar content in the former and a high starch content in the latter. The Montana Station has shown further that there is a variation in the vitamin content of potatoes whether stored over winter in warm, dry storages or in cool, humid storages, and the Missouri Station is raising a question as to the vitamin content of apples stored over winter.

It thus seems likely that a storage which is suitable for one fruit or vegetable product may be entirely inadequate for or even harmful to another product. It appears, therefore, that coordinated studies of the pathological, biochemical, nutritional, and engineering factors involved in the economic storage of fruit and vegetable products, which will establish, under controlled conditions, the storage requirements of each product and permit the development of engineering principles to adequately meet these requirements will be well worth while. The development of the control technique and of the features of the storage structures as engineering functions offers quite promising lines for research.

INSECT AND PLANT DISEASE CONTROL

The control of plant diseases and insect pests offers a problem of considerable economic importance in connection with field, vegetable, and fruit crop production.

European Corn Borer.--The European corn-borer control work presents one of the biggest opportunities so far encountered for the development of mechanical methods in insect control and much of a generally practical nature has already been accomplished in this respect. The evidence so far available empha-

sizes the importance, however, of close and effective coordination of the entomological, agronomic, and agricultural engineering forces engaged in the work with the economical production of a satisfactory corn crop as the practical aim. The requirements of the crop must be considered as well as the requirements for the destruction of the corn borer, which imposes a double responsibility on the agricultural engineers engaged in the development of mechanical corn-borer control methods and equipment. The field of engineering research in this connection is now being organized and clarified in the light of the available knowledge of the life history and habits of the corn borer, and appears to offer numerous profitable lines of investigation for experiment stations to which the corn borer is or may be a problem.

Curly Top Disease.--The curly top disease of sugar beets is an especially important economic problem in some of the western States and it appears that the beet leaf hopper is one of the most active agents in its spread. Apparently the nature of the disease itself is not known so that efforts at preventing its spread have been centered largely on the control of the leafhopper. In this connection the idea of destroying the leaf hopper by electrocution has been developed and a study by entomologists and engineers of the electrocution requirements of this insect leading to the development of practical electrical field equipment to meet these requirements has already made some progress at one of the stations. This type of undertaking appears to offer a rather promising line of engineering investigation in localities where the curly top infestation is economically important.

Spraying and Dusting.--In spraying and dusting work for disease and insect control, the problem is twofold involving the difficulties of effective mixing, projecting, and proper depositing of known sprays and dusts as well as the necessity for considering the item of excessive power and labor expenditure. The

former has already been found to call for a rather intricate manipulation of engineering mechanics and physics which must consider the physical characteristics of the dusting and spraying materials under different conditions in connection with the mechanical requirements for their proper and effective use. The economic importance of the truck and fruit industry in many localities points to the value of engineering research which will introduce greater efficiency and economy into spraying and dusting operations.

LAND RECLAMATION

Land reclamation measures may be considered to include among other things such practices as drainage and irrigation. Much of a practical nature has been done in the past with available engineering knowledge by agricultural engineers in these important lines. However, the cost of drainage and irrigation practices is now assuming a position of considerable importance in the total cost of agricultural production in some localities, and the necessity for a maximum of economy and effectiveness in the methods and permanency in the structures used is quite pressing. This means that the traditional empirical and more or less standardized methods of designing and installing drains in any wet soil must give way to drainage practices based upon engineering principles carefully worked out to meet the conditions presented by individual soils. In like manner empirical irrigation practices growing out of time-honored duty of water tests, for example, must give way to methods of water application based upon the specific requirements of individual crops and soils. This conception of a profitable field of research has already led some experiment stations into undertakings which coordinate the forces of agronomy, plant physiology, soil technology, and agricultural engineering in an effort to establish the principles governing water movement, water loss, and the availability of moisture to different crops, in individual soils under definite conditions. Several agricultural

research institutions in Europe and South America have also recognized the economic importance of work of this character. The obvious purpose is to fully elucidate these principles and to determine how the factors involved may be advantageously and most economically influenced by the use of the hydraulic engineering principles employed in drainage and irrigation practices. The Michigan, Minnesota, Utah, and California Experiment Stations have been especially active in this work and the results so far obtained would suggest this field as being a promising one for agricultural engineering participation.

CONTROL OF SOIL EROSION

The work in soil erosion control and prevention is a field of agricultural conservation which for success has been found to require in its study a coordination of the forces of agronomy, soil technology, and agricultural engineering. Erosion is now recognized as practically an individual soil problem and engineering efforts to develop methods and structures to control or prevent it must be aimed at the characteristics and requirements of individual soils. Studies in progress on soil erosion at the Texas, Missouri, and North Carolina Stations have already defined some of the specific problems involved in soil erosion control. The results of this work so far, together with the statistics available as to the economic importance of erosion losses from agricultural lands present considerable evidence that this line of work is profitable as an agricultural engineering undertaking in States where soil erosion is a problem.

FARM HOME MANAGEMENT

The comparatively recent inauguration of the national movement toward the introduction of greater economy of time and labor into the operations of the farm home has brought to light a number of rather knotty problems relating to the development and use of labor-saving equipment. Much has already been accomplished in saving labor in the farm home by home management specialists. It

is being realized, however, that an intelligent coordination of home management and engineering forces in the effort to introduce greater convenience, comfort, and economy of time and labor into home-making practices is likely to produce results more quickly and in a permanently satisfactory manner. Such cooperation is tending to develop the principles involved in individual operations such as cooking, laundering, cleaning, and the like, and the requirements corresponding to them which the engineer must meet either by the proper manipulation of available equipment or by the development of the specifications for new equipment. The Iowa Station was one of the first to recognize the soundness and value of this procedure and to act accordingly, and work of a similar nature is now under way elsewhere, notably at the Washington and North Dakota Stations. The opportunity for agricultural engineering participation seems particularly promising in this field, especially where the manipulation of mechanical or electrical principles and equipment are involved. In the development of standards and requirements for the testing of cooking, heating and laundering equipment for example, adequate control technique is necessary and its provision is an important engineering function. This, together with the testing and development of equipment offers a practically new field of engineering investigation which is of considerable economic importance in the farm home.

USE OF ELECTRICITY IN AGRICULTURE

The use of electricity as a source of energy in agricultural practices has undergone considerable development during the past four years, especially since the National Committee on the Relation of Electricity to Agriculture and its auxiliary State committees have been organized. Much of a practical nature has been accomplished in those localities where electrical energy has been available.

As pointed out in a report emanating from the Office of Experiment Stations in 1924 on "Some Research Features of the Application of Electricity to Agriculture,"* the opportunities offered by electricity for the scientific and economic development of agriculture are so great as to demand serious and intelligent consideration. In this connection all the facts regarding the exact requirements of agricultural processes and practices must be known in order to use electricity most effectively and economically.

It has been found that features of most of the major agricultural practices have some use for electricity. This is true in features of crop production and use such as in crop processing and drying for example, in animal production, and especially in home management. Several of the experiment stations have identified specific problems and are now undertaking their study. Notable examples are the work at the California Station on the development of electrical dairy equipment, at the Oregon Station in the development of electrical poultry production equipment and at the Wisconsin and Minnesota Stations on the use of electricity in the operation of stationary power machinery.

A coordination of the efforts of subject-matter specialists in agriculture and of agricultural engineers appears necessary in all this work. While much of it is of rather general character it seems likely that some of the specific problems involved offer promising lines of engineering research which the experiment station can well look into.

*Agricultural Engineering, Vol. 5, (1924), No. 8, pp 180-185; No. 9, pp 203-208.

CONCLUSION

This study of experiment station work indicates that an almost unlimited field of agricultural engineering investigation already lies in existing research programs at the agricultural experiment stations, much of which is quite promising in nature. A few typical examples of such lines of work have been suggested to show their origin and nature. All of these cases are alike in that the need for engineering participation arises from some very definite agricultural problem.

Such agricultural engineering participation in the study of agricultural problems may take the form of the manipulation of engineering principles to introduce control into experiments, the testing or comparing of available equipment or the development of new equipment on the basis of known standards or established requirements, or original research to establish the fundamental principles involved in operations to provide a basis for the rational development of the necessary equipment.

Success in this work appears to call for the effective coordination of the efforts of subject-matter specialists in agriculture and of those of agricultural engineers in the study of specific problems.